CLAIMS

1. A facial expression transformation method comprising:

defining a code book containing data defining a first set of facial expressions of a first person;

providing data defining a second set of facial expressions, the second set of facial expressions providing a training set of expressions of a second person who is different from the first person;

deriving a transformation function from the training set of expressions and corresponding expressions from the first set of expressions; and

applying the transformation function to the first set of expressions to provide a synthetic set of expressions.

2. The method of claim 1, wherein the training set of expressions contains fewer expressions than the code book.

3. The method of claim 1, wherein the transformation function compensates for differences in the size and shape of the faces of the first and second persons.

4. The method of claim 1, wherein said deriving of the transformation function comprises computing a linear transformation from one set of expressions to another.

5. The method of claim 1, wherein the deriving of the transformation function comprises:

representing each expression as a $3m$-vector that contains x, y, z displacements at m standard sample positions; and

computing a set of linear predictors a_j, one for each coordinate of g_a, given a set of n expression vectors for a face to be transformed, $g_{a1...n}$, and a corresponding set of vectors for a target face, $g_{b1...n}$, by solving $3m$ linear least squares systems of the following form:

$$a_j \cdot g_{ai} = g_{bi}[j],\ i = 1...n$$

6. The method of claim 5, wherein said computing comprises using only a subset of points for each g_{aj}.

7. The method of claim 6, wherein said using comprises using only points that share edges with a standard sample point under consideration.

8. The method of claim 5 further comprising controlling the spread of singular values when computing a pseudoinverse to solve for the a_j.

9. The method of claim 8, wherein said controlling the spread comprises zeroing out all singular values less than $\alpha\sigma_1$, where σ_1 is the largest singular value of the matrix.

10. The method of claim 1, wherein said providing data defining a second set of facial expressions comprises:

illuminating the second person's face with illumination; and

contemporaneously capturing structure data describing the face's structure and reflectance data describing reflectance properties of the face from the illumination.

11. The method of claim 10, wherein said illuminating comprises:

using multiple light sources, one of which projecting a pattern on the second person's face from which the structure data can be ascertained;

at least one of the light sources comprising an infrared light source;

at least one of the light sources being polarized; and

said capturing comprising using a camera having a polarizer that suppresses specularly-reflected light so that diffuse component reflection data is captured.

12. The method of claim 1, wherein said providing data defining a second set of facial expressions comprises:

illuminating the second person's face with a first polarized light source that is selected so that specularly-suppressed reflective properties of the face can be ascertained;

illuminating the second person's face with a second structured light source that projects a pattern onto the face, while simultaneously illuminating the face with the first polarized light source; and

capturing both specularly-suppressed reflection data and structure data from the simultaneous illumination.

13. The method of claim 12, wherein the light sources provide light at different frequencies.

14. The method of claim 12, wherein the light sources provide infrared light.

15. The method of claim 12, further comprising processing the captured data to provide both (a) data that describes dimensional aspects of the face and (b) data that describes diffuse reflective properties of the face.

16. The method of claim 1, wherein said providing data defining a second set of facial expressions comprises:

illuminating the second person's face with multiple different light sources;

measuring range map data from said illuminating;

measuring image data from said illuminating;

deriving a 3-dimensional surface from the range map data;

computing surface normals to the 3-dimensional surface; and

processing the surface normals and the image data to derive an albedo map.

17. The method of claim 16, wherein at least one of the light sources is polarized.

18. The method of claim 16, wherein all of the light sources are polarized.

19. One or more computer-readable media having computer-readable instructions thereon which, when executed by a computer, cause the computer to:

operate on a training set of expressions from one person and corresponding expressions from a code book of another person to compute a linear transformation function from the training set and their corresponding expressions; and

apply the transformation function to a plurality of expressions from the code book to provide a synthetic set of expressions.

20. The computer-readable media of claim 19, wherein the instructions cause the computer to use the synthetic set of expressions to transform expressions from the one person into expressions of the other person.

21. The computer-readable media of claim 20, wherein the instructions cause the computer to transform expressions from the one person that are different from those expressions comprising the code book expressions.

22. The computer-readable media of claim 20, wherein the instructions cause the computer to transform expressions by transmitting at least one index of a synthetic expression to a receiver that can reconstruct the expression.

23. The computer-readable media of claim 20, wherein the instructions cause the computer to transform facial expressions.

24. A facial expression transformation system comprising:

a code book embodied on a computer-readable medium, the code book containing data defining a first set of facial expressions of a first person;

data embodied on a computer-readable medium, the data defining a second set of facial expressions, the second set of facial expressions providing a training set of expressions of a second person who is different from the first person; and

a transformation processor configured to derive a transformation function from the training set of expressions and corresponding expressions from the first set of expressions.

25. The expression transformation system of claim 24, wherein the transformation processor comprises a linear transformation processor.

26. The expression transformation system of claim 24 further comprising a synthetic set of expressions embodied on a computer-readable medium, the synthetic set of expressions being derived by applying the transformation function to the code book expressions.

27. The expression transformation system of claim 24, wherein the transformation function compensates for differences in the size and shape of the faces of the first and second persons.

28. The expression transformation system of claim 24, wherein the transformation processor derives the transformation function by:

representing each expression as a $3m$-vector that contains x, y, z displacements at m standard sample positions; and

computing a set of linear predictors a_j, one for each coordinate of g_a, given a set of n expression vectors for a face to be transformed, $g_{a1...n}$, and a corresponding set of vectors for a target face, $g_{b1...n}$, by solving $3m$ linear least squares systems of the following form:

$$a_j \cdot g_{ai} = g_{bi}[j], i = 1...n$$

29. A facial expression transformation system comprising:

a transmitter comprising:

a facial illumination system that is configured to provide multiple different light sources at the same time for illuminating a subject's face;

a data-capturing system configured to capture both structure data and reflectance data from the subject's face when illuminated by the facial illumination system; and

a first code book of synthetic expressions that have been synthesized by:

receiving a training set of expressions provided by the subject;

computing a transformation function using the training set of expressions and corresponding unsynthesized code book expressions; and

applying the transformation function to all of the expressions in the code book; and

a receiver communicatively linked with the transmitter and comprising:

a reconstruction module for reconstructing facial images; and

a second code book containing the same synthetic expressions as the first code book; and

the transmitter being configured to:

capture additional expressions of the subject;

search the first code book for a corresponding or near matching expression; and

transmit an index of a corresponding or matching code book expression to the receiver for facial image reconstruction by the reconstruction module.

30. The expression transformation system of claim 29, wherein the illumination system comprises at least one polarized light source.

31. The expression transformation system of claim 29, wherein the illumination system comprises multiple polarized light sources.

32. The expression transformation system of claim 29, wherein the illumination system comprises a patterned light source configured to project a pattern onto the subject's face.

33. The expression transformation system of claim 29, wherein the illumination system comprises an infrared patterned light source configured to project a pattern onto the subject's face.

34. The expression transformation system of claim 29, wherein the different light sources are all infrared light sources.

35. A method of animating facial features comprising:

defining a subdivision surface that approximates geometry of a plurality of different faces; and

fitting the same subdivision surface to each of the plurality of faces.

36. The method of claim 35, wherein said defining comprises defining the subdivision surface with a coarse mesh structure.

37. The method of claim 36, wherein the coarse mesh structure comprises a triangular mesh.

38. The method of claim 35, wherein said fitting comprises performing a continuous optimization operation over vertex positions of the subdivision surface.

39. The method of claim 35, wherein said fitting comprises fitting the subdivision surface to the faces without altering the connectivity of a mesh that defines the subdivision surface.

40. The method of claim 35, wherein said fitting comprises minimizing a smoothing functional associated with a mesh that defines the subdivision surface.

41. The method of claim 35, wherein said fitting comprises selecting one or more constraints associated with a mesh that defines the subdivision surface and fitting those constraints directly to corresponding points on the faces.

42. The method of claim 41, wherein the constraints are associated with one of the eyes, nose and mouth.

43. The method of claim 35, wherein said fitting comprises minimizing a functional that includes terms for distance, smoothness, and constraints.

44. The method of claim 35, wherein said fitting comprises solving a sequence of linear least-squares problems.

45. One or more computer-readable media having computer-readable instructions thereon which, when executed by one or more computers, cause the one or more computers to implement the method of claim 35.

46. A method of animating facial features comprising:

defining a subdivision surface that approximates geometry of a plurality of different faces;

fitting the same subdivision surface to each of the plurality of faces to establish a correspondence between the faces; and

using the correspondence between the faces to transform an expression of one face into an expression of another face.

47. A method of animating facial features comprising:

measuring 3-dimensional data for a plurality of different faces to provide corresponding face models;

defining only one generic face model that is to be used to map to each corresponding face model;

selecting a plurality of points on the generic face model that are to be mapped directly to corresponding points on each of the corresponding face models; and

fitting the generic face model to each of the corresponding face models, said fitting comprising mapping each of the selected points directly to the corresponding points on each of the corresponding face models.

48. The method of claim 47, wherein:

said defining comprises defining a subdivision surface from a base mesh structure, the subdivision surface containing a plurality of vertices and approximating the geometry of the face models; and

said fitting comprises manipulating only the positions of the vertices of the subdivision surface.

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49. The method of claim 47, wherein said fitting comprises manipulating a base mesh that defines a subdivision surface.

50. The method of claim 47, wherein said fitting comprises manipulating a base mesh that defines a subdivision surface without altering the connectivity of the base mesh.

51. The method of claim 47, wherein said measuring comprises using a laser range scan to measure the 3-dimensional data.